SOP-15
Continuous Particulate Air Sampling

Yerington Mine Site
Standard Operating Procedure

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SOP-15

CONTINUOUS PARTICULATE AIR SAMPLING

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1.0 OBJECTIVE

The objective of this document is to establish a standard operating procedure (SOP) for real time, continuous particulate air sampling in ambient air. The SOP is derived from RTP Environmental Associates, Inc. document *SOP 169 – TEOM 1400 PM_{10} Monitor, Revision 2* (RTP, 2002) by permission of Mark Podrez.

2.0 DEFINITIONS

ACCU. Automatic Cartridge Collection Unit associated with the Thermo Electron TEOM Series 1400a continuous particulate air sampler.

Continuous Air Sampler. Air sampling equipment that provides continuous instantaneous measurements. The equipment is often hand-held, battery-operated, and passive, but some have active sampling and are stationary. Passive sampling devices are not equipped with an air pump and are typically used for indoor applications. Active sampling is more appropriate for ambient applications since a low flow (i.e., flow rates in L/min) air pump constantly draws air into the detector. Most real time particulate air samplers measure a subset of TSP (e.g., PM_{10} or $PM_{2.5}$). Active sampling devices can be hand-held or stationary.

High Volume Air Sampler. Air sampling equipment capable of sampling high volumes of air (typically 57,000 ft^3 or 1,600 m^3) at high flow rates (typically 113 m^3/min or 40 ft^3/min) over an extended sampling duration (typically 24 hrs).

NAAQS. National Ambient Air Quality Standard as specified in the Clean Air Act Amendments of 1990. The U.S. EPA provides NAAQS for six criteria air pollutants: carbon monoxide, lead, nitrogen dioxide, particulate matter as PM_{10} and $PM_{2.5}$, ozone, and sulfur dioxides. The current primary standard for PM_{10} is 50 µg/m^3 averaged over a year at each monitoring location. Each location may have no more than one measurement per year above 150 µg/m^3 averaged over 24 hrs.

Particulate Matter. Material suspended in the air in the form of solid particles or liquid droplets (i.e., aerosols).

$PM_{2.5}$. Fine particulate matter with an aerodynamic diameter of 2.5 µm or less. $PM_{2.5}$ is a subset of TSP that can lodge deeply into the lungs and are believed to post the largest health risks. Sources of fine particles include all types of combustion (motor vehicles, power plants, wood burning, etc.) and some industrial processes. In 1997, EPA established a NAAQS for $PM_{2.5}$ for the first time as well as a revised NAAQS for PM_{10}.

PM_{10}. Particulate matter with an aerodynamic diameter of 10 µm or less. PM_{10} is a subset of TSP (typically 40 to 50%) that can be inhaled and accumulate in the respiratory system. Particles with diameters between 2.5 and 10 µm are referred to as "coarse." Sources of coarse particles include crushing or grinding operations, and dust from paved or unpaved roads.

Real Time Air Sampler. See definition of continuous air sampler.

TEOM. Patented Tapered Element Oscillating Microbalance technology associated with the Thermo Electron TEOM Series 1400a continuous particulate air sampler.

TSP. Total suspended particulates. Prior to 1987, the NAAQS for particulate matter was measured as TSP.

Units. The following units are used in this SOP:

- ft^3 = cubic feet (volume)
- ft^3/min = cubic feet per minute (flow rate)
- L/min = liters per minute (flow rate)
- m^3 = cubic meters (volume)
- m^3/min = cubic meters per minute (flow rate)
- mm Hg = millimeters of mercury (pressure)
- psi = pounds per square inch (pressure)
- µg = micrograms (mass)
- µg/m^3 = micrograms per cubic meter (concentration)
- µm = micrometers or "microns" (length)

3.0 APPLICABILITY

This SOP applies to continuous, real time monitoring of particulates in ambient (i.e., outdoor) air in applications such as environmental remedial actions and general construction activities. This SOP may also be used to help estimate fugitive dust emissions from a mine, agricultural area, or industrial operation. This SOP does not apply to high volume air sampling of ambient air nor does it apply to air sampling techniques typically used to evaluate worker exposure in an indoor workplace. This procedure represents general minimum standards and may be modified or supplemented as needed for a specific project by site-specific documents such as a quality assurance project plan, work plan, field sampling plan, or health and safety plan.

4.0 RESPONSIBILITY

The Project Manager, or designee, will have the responsibility to oversee and ensure that the air sampling is implemented according to this SOP and any site-specific documents. The field personnel will be responsible for understanding and implementing this SOP and related SOPs during field activities, as well as obtaining the appropriate field logbooks, forms and records necessary to complete the field activities.

5.0 REQUIRED MATERIALS

The following equipment and supplies are required for Brown and Caldwell representatives for this SOP. Note that this SOP is based on the use of a TEOM Series 1400a continuous particulate air sampler manufactured by Thermo Electron Corporation (previously Rupprecht & Patashnick). Use of this SOP with a continuous particulate air sampler from another manufacturer is not recommended.

- Thermo Electron TEOM Series 1400A continuous particulate air sampler. The equipment has received U.S. EPA PM_{10} equivalency approval EQPM-1090-079.
- Permanent electrical power supply consisting of 120 V AC, 60 Hz, and 5.25 A or 240 V AC, 50 Hz, and 3.25 A
- Optional Thermo Electron ACCU and 47-mm Teflon filter cassettes
- Optional outdoor enclosure equipped with heating and air conditioning. The enclosure can be either a Thermo Electron Complete Outdoor Enclosure or a custom built shed on a 6-foot by 4-foot concrete pad. On the custom shed, the TEOM inlet will protrude through the roof such that the sampling elevation will be at approximately 4 meters.
- Thermo Electron Mass Calibration Verification Kit
- Bios DryCal ® DC-Lite flow calibrator
- Chronograph (digital watch), thermometer, and barometric pressure gauge (required for calibration)
- Wind sock for approximating wind speed and wind direction (required for data interpretation)
- Meteorological station (optional, but highly recommended) that provides 15-minute measurements of temperature, barometric pressure, wind speed, and wind direction
- Miscellaneous tools: a set of flat-head and Phillips screwdrivers, a socket wrench set, a combination wrench set, pliers, etc.
- Gloves (latex or nitrile) for handling filters
- Large Zip-lock bags (to hold filter/manila folder)
- Small Fed-Ex box for shipping samples
- Field notebook, Site Check Record, and indelible pen
- First-aid kit and fire extinguisher
- Personnel Protective Equipment (PPE) as specified in the site-specific health and safety plan

The TEOM air sampler consists of two basic components: the sensor unit (containing the sample inlet and mass transducer) and the control unit (containing the operator terminal and control electronics). These are connected by a 10-meter (optionally 2 or 20 m) cable/tube assembly. The control unit is suitable for standard 19" rack mounting and may be located in any convenient indoor location which is maintained between 10 and 30 °C.

The manufacturer strongly recommends that the sensor unit of the TEOM air sampler also be installed indoors or in a weather-proof enclosure. In this case, a sampling tube is fed through the roof of the enclosure. Although the TEOM monitor is inherently rugged, it is nevertheless a precision instrument representing a significant financial investment. Best operation and longevity will be obtained if the unit is not exposed to extremes of weather. Filter change out, in particular, may be best accomplished by a technician operating in a comfortable environment where there is no possibility of rain or snow landing on the filter. The sample line should proceed in a straight line from the PM-10 Inlet to the inlet of the sensor unit through a 4 cm (1.5 inch) diameter hole in the roof of the enclosure. Refer to Section 2 of the manufacturer's manual for detailed installation instructions, and Section 4 for startup information.

6.0 METHODS

PM_{10} sampling will be conducted in accordance with *40 CFR 50, Appendix J Reference Method for the Determination of Particulate Matter as PM-10 in the Atmosphere* (U.S. EPA, 1998). The sampling will involve collecting an integrated (i.e., continuous) 24-hour air sample from midnight to midnight on the target day. Note that although the TEOM unit operates continuously, the method indicates that the 24-hour average PM_{10} is determined from midnight to midnight on the target day.

The following sections describe methods for: pre-sampling activities; calibration, operation, and maintenance of the continuous particulate air samplers.

6.1 Pre-Sampling Activities

The following activities will be conducted prior to sampling:

- Procure equipment from manufacturer or supplier (may require up to several weeks and can be costly if not shipped by ground);
- Assemble and calibrate equipment and become familiar with operation;
- Determine predominant wind direction (optional, but highly recommended);
- Establish monitoring locations (e.g., upwind, downwind, or near sensitive receptors) by reviewing data from the nearest meteorological station or by using dispersion modeling;
- Construct monitoring locations with permanent electrical supply; and
- Procure sample filter cassettes from laboratory (if using the ACCU system).

6.2 Calibration

This section describes the calibration methods for the TEOM monitor as well as the method for auditing flow rates. The routine calibration intervals recommended for the TEOM monitor are summarized below.

- Flow controller calibration every 3 months (quarterly)
- Mass calibration verification every 12 months (annually)
- Ambient temperature and barometric pressure calibration every 3 months (quarterly)
- Analog calibration every year (annually)

6.2.1 Leak Testing

The TEOM monitor provides accurate results only if no leaks exist in the flow handling system. The following calibration method will be used to assure no leaks exist.

1) Press the <Data Stop> key on the control unit's keypad.
2) Remove the TEOM filter cartridge from the mass transducer according to the instructions in Section 6.5.2. This prevents accidental damage from occurring to the sample filter cartridge when exposed to the high-pressure drop (vacuum) in the sample line that the leak check creates.
3) With the instrument displaying the Main Screen, read the Main Flow and Auxiliary Flow on the four-line alphanumeric display.
4) Determine the flow controller offset values by turning the pump off, waiting until the flow readings stabilize, and record the offset values.
5) Turn the pump on.
6) Locate the Flow Audit Adapter and ensure that the valve of the adapter is in its open position.
7) Remove the size-selective inlet from the flow splitter and replace it with the Flow Audit Adapter.
8) Slowly close the valve located on the Flow Audit Adapter.
9) Wait until the flow readings stabilize, and record the values.
10) The Main Flow reading, minus the Main Flow offset reading, should be less than 0.15 L/min. The Auxiliary Flow reading, minus the Auxiliary Flow offset reading, should be less than 0.65.
11) If the leak test indicates a problem, check hose fittings and other critical locations in the flow system for leaks.
12) Slowly open the value located on the flow audit adaptor.
13) Remove the Flow Audit Adapter from the Flow Splitter.
14) Replace the sample inlet on the Flow Splitter.
15) Replace the TEOM filter cartridge in the mass transducer.

6.2.2 Flow Control Calibration

This method allows the operator to calibrate the sample and bypass flow rates. Follow the following steps below to perform a calibration of the flow controllers. Note the operator must perform the ambient temperature and barometric pressure calibration, and leak check before executing the flow procedure.

1) Perform a leak check.
2) Locate the flow audit adapter and ensure that the valve of the adapter is in its open position.
3) Remove the size-selective inlet from the flow splitter and replace it with the Flow Audit Adapter. Make sure the Flow Audit Adaptor is in the open position.
4) When in the Main screen, scroll down to the "Main Flow" and "Aux Flow" lines. These values represent the actual volumetric flows as measured by the monitor's flow controllers.
5) Confirm that these flows are within ± 2% of their set points (3.0 L/min for the "Main Flow" and 13.67 L/min for the "Aux Flow"). Any greater deviation may indicate that the in-line filters are plugged or other blockages exist in the system.

6) Attach a reference flow meter such as a bubble meter, dry gas meter, or mass flow meter to the top of the Flow Audit Adapter. This reference flow meter should have been recently calibrated to a primary standard, have an accuracy of ± 1% at 3 L/min and 16.67 L/min, and a pressure drop of less than 0.07 bar (1 psi).

7) Read the total flow (approximately 16.67 L/min) on the reference flow meter. The total volumetric flow measured by the reference flow meter must be 16.67 ± 1.0 L/min to be acceptable.

8) Disconnect the bypass flow line from the bypass extension on the bottom of the flow splitter located at the sample inlet.

9) Cap the exit of the flow splitter bypass extension with the 3/8-inch Swagelok cap.

10) Read the main flow (approximately 3.0 L/min) on the reference flow meter. The volumetric flow measured by the reference flow meter must be 3.0 ± 0.2 L/min to be acceptable.

11) If the flows differ by more than 7%, a software calibration must be performed (refer to the following section of this SOP for the method).

12) If the flow readings are within acceptable limits, remove the 3/8-inch Swagelok cap from the flow splitter bypass extension.

13) Install the bypass flow line onto the flow splitter bypass extension.

14) Perform a leak check.

15) Remove the flow audit adapter from the top of the flow splitter.

16) Install the sample inlet onto the flow splitter.

17) Install a new TEOM filter into the mass transducer.

18) Press <F1> or <Run>.

6.2.3 Flow Controller Software Calibration

The following method shall be performed to calibrate the Flow Controller Software.

1) Turn off the TEOM Control Unit.

2) Disconnect the electric cable that links the control unit with the sensor unit.

3) Remove the main and bypass flow lines from their connections on the back panel of the TEOM Control Unit.

4) Turn on the TEOM Control Unit, and make sure that the pump is on.

5) Display the Set Temps/Flows Screen on the instrument by selecting "Set Temps/Flows" from the Menu Screen, or by typing 19<Enter>. Position the screen so that "F-Main" and "F-Aux" appear. Record the set points for the main and auxiliary flows.

6) Position the cursor so that the lines entitled "T-A/S" and "P-A/S" appear on the screen. Note the existing settings for Average Temperature (on the left) and Average Pressure (on the left). If the monitor is not in the Setup Mode, press <Data Stop>. Then set the Average Temperature and Average Pressure to the current local conditions at the flow meter.

7) Position the cursor so that the lines entitled "FAdj Main" and "FAdj Aux" appear on the screen.

8) Attach a reference flow meter such as a bubble meter, dry gas meter, or mass flow meter to the location labeled “Sensor Flow” on the back panel of the TEOM Control Unit. This reference flow meter should have been recently calibrated to a primary standard, and should have an accuracy of 1% at 3 L/min.
9) Compare the TEOM Series 1400a set point recorded in Step 5) above with the flow rate indicated by the flow meter. This set point indication is in volumetric L/min. If a mass flow meter is being used, its reading must be adjusted for temperature and pressure to obtain volumetric flow under the test conditions. No adjustment is necessary in the case of a volumetric flow meter.
10) If the flows differ by more than 7%, edit the values for “FAdj Main” so that the volumetric flow rates indicated by the flow meter match the set point recorded in Step 5) above.
11) If a step adjustment greater than ± 10% would be necessary to calibrate the mass flow controller, a hardware calibration must be performed (refer to Section 8.4 of the manufacturer’s manual for procedures).
12) Change the values for Average Temperature and Average Pressure back to their original values recorded in Step 6) (i.e., the values for automatic measurement, or the seasonal average temperature and barometric settings).
13) Turn off the TEOM Control Unit.
14) Re-attach the air lines to the back panel of the TEOM Control Unit.
15) Re-connect the electric cable that links the control unit with the sensor unit.
16) Turn on the TEOM Control Unit.
17) Perform a leak check.

6.2.4 Mass Transducer Calibration

The calibration of the TEOM mass transducer in the TEOM Series 1400a continuous air sampler is determined by the mass transducer’s physical mechanical properties. Under normal circumstances the calibration does not change materially over the life of the instrument. Contact the manufacturer if the results of the verification procedure described in this Section indicate a calibration constant that differs by more than 2.5% from the original manufacturer calibration constant.

The TEOM Series 1400a continuous air sampler is calibrated using a pre-weighted “certified” TEOM filter as a calibration weight. Since the mass of the filter with particulate differs from the mass of a new filter by only a small fraction, calibrating the system with a calibration filter allows all measurements to be made at essentially the same operating point as the original calibration. The calibrated filter can only be used a maximum of ten times, to ensure that the actual weight of the filter is near the original certified weight.

The K0 Confirmation Screen accessible through the Menu Screen of the instrument allows the user to verify the calibration of the TEOM monitor without having to perform any computations. Enter the K0 Confirmation Screen by selecting “K0 Confirmation” from the Main Menu or by entering 17<Enter> from any screen. Perform the following steps to confirm the system's mass calibration using a Mass Calibration Verification Kit with the K0 Calibration Screen displayed on the monitor:

1) Press <Data Stop>.
2) Remove the TEOM filter cartridge from the mass transducer according to the instructions in Section 6.5.2.
3) Type 17<Enter> on the keypad.
4) When in the KO Confirmation Screen, Input the weight of the pre-weighed calibration filter on the line labeled “Filt Wght.”
5) Press <Edit>.
6) Scroll to the “Filt Wght” field.
7) Enter the weight of the pre-weighed filter.
8) Operate the system without a filter and wait for the oscillating frequency shown in the upper right-hand corner of the screen to settle.
9) Press the <First/Last> key to record the frequency “f_o” once the frequency has stabilized.
10) Install the calibration verification filter in the instrument and wait for the frequency to stabilize again.
11) Press the <First/Last> key again to record the frequency “f_1” once the frequency has stabilized.
12) The instrument then automatically computes and displays the audit value of the calibration constant, “K_o” on the line entitled “Audit K0.” The K0 Confirmation Screen also displays the current “K_o” value entered in the monitor, as well as the percentage difference between the audit and currently-entered “K_o” values.

If mistakes are made in executing any of the steps described above, exit from the K0 Confirmation Screen and re-enter it. All values are shown as “0” upon re-entering the screen.

6.2.5 Ambient Temperature and Barometric Pressure Calibration

Perform the following steps to verify the ambient temperature.

1) Display the Set Temps/Flows Screen on the instrument by selecting “Set Temps/Flows” from the Menu Screen, or by typing 19<Enter>.
2) When in the Set Temps/Flows screen, locate the current ambient temperature reading in the “Amb Temp” field.
3) Determine the current temperature (°C) at the ambient temperature sensor using an external thermometer (°C = 5/9 x (°F – 32)).
4) Verify that the value of the “Amb Temp” field is within ± 1 °C of the measured temperature. If this is not the case, perform the ambient temperature calibration procedures below.

Perform the following steps to verify the barometric pressure.

1) Access the Set Temps/Flows screen.
2) When in the Set Temps/Flows screen, locate the current ambient temperature reading in the "Amb Pres" field.
3) Determine the current barometric pressure in mm Hg (absolute pressure, not corrected to sea level). Verify the monitor's barometric pressure by measuring the current barometric station pressure in mm Hg with and external measurement device. To convert from atmospheres at 0°C to mm Hg, multiply by 760. To convert from inches Hg at 32°F to mm Hg, multiply by 25.4. To convert from millibars to mm Hg, multiply by 0.75012.
4) Verify that the value of the "Amb Pres" field is within ± 10 mm Hg of the measured barometric pressure. If this is not the case, perform the barometric pressure calibration procedures below.

Perform the following steps to calibrate the ambient temperature sensor.

1) Perform the analog calibration procedure (Section 3.2.1 in the manufacturer's service manual).
2) Obtain the current temperature at the ambient temperature probe in degrees Celsius.
3) Remove the top cover of the control unit.
4) Display the ambient temperature reading in the Set Temps/Flows Screen.
5) Locate the analog board. It is the L-shaped board mounted on top of the CPU.
6) Adjust the potentiometer for analog input 8 on the analog board until the ambient temperature matches the actual temperature reading.
7) Wait 30 seconds for the reading to stabilize and readjust, if necessary.
8) Replace the top cover on the control unit.

Perform the following steps to calibrate the barometric pressure sensor.

1) Perform the analog calibration procedure (Section 3.2.1 in the manufacturer's service manual).
2) Obtain the current barometric pressure (absolute pressure, NOT corrected to sea level) in atmospheres.
    - To convert from mm Hg at 0°C to atmospheres, multiply by 0.001316.
    - To convert from inches Hg at 32°F to atmospheres, multiply by 0.03342.
    - To convert from millibars to atmospheres, multiply by 0.000987.
3) Remove the top cover of the control unit.
4) Locate the interface board on the back panel of the control unit.
5) Place the positive lead of the digital multimeter on the test point labeled "+10 V" (red) and the negative lead on test point GND (black).
6) Locate potentiometer R304, and adjust it until the reading is 10.000 V DC ± 0.001 V.
7) Display the ambient pressure reading in the Set Temps/Flows Screen.
8) Adjust potentiometer R509 until the display matches the actual pressure reading.

9) Wait 30 seconds for the reading to stabilize and readjust, if necessary.
10) Replace the top cover on the control unit.

6.4 Maintenance

This section describes the routine maintenance for the TEOM air sampler. The routine maintenance intervals recommended for the equipment are summarized below.

- Inspect/clean PM_{10} inlet every 3 months (quarterly)
- Replace large bypass in-line filters every 6 months (semi-annually)
- Clean air inlet system every 12 months (annually)
- Perform leak test every 3 months (quarterly) or after any component in the flow system is replaced
- Rebuild sample pump every 18 months

6.4.1 Cleaning the PM-10 Inlet

The PM-10 Inlet must remain free of significant contamination to ensure a correct particulate size cut-off at 10 µm. PM-10 Inlet cleaning is best done immediately following an exchange of a TEOM filter cartridge. This allows for the cleaning procedure to be carried out during the one-half hour flow and temperature stabilization period following the instrument reset. Remove the PM-10 Inlet from the Flow Splitter by simply lifting it off. It is recommended that the PM-10 Inlet be disassembled and cleaned following the maintenance procedures in the manufacturer's service manual Appendix F. Most of the contamination collects on the impaction plate in the collector assembly.

6.4.2 Replacing the Large Bypass In-Line Filters

The Large Bypass In-Line Filters, located on main and bypass flow lines on the back of the TEOM Control Unit, are designed to provide the user of the TEOM monitor a long replacement interval (6 months recommended). Replacement of the Large Bypass In-Line Filters is best done immediately following an exchange of a TEOM filter cartridge. This allows for the exchange to be carried out during the one-half hour flow and temperature stabilization period following the instrument reset. To replace the filters, remove the existing filters with their quick-connect fittings and replace them with new filter assemblies. Ensure that the arrows on the filters point away from the sensor unit (against the flow). Perform a leak check after the in line filters are replaced.

6.4.3 Cleaning the Air Inlet System

The heated Air Inlet in the TEOM air sampler must be cleaned periodically to remove the build-up of particulate on its inner walls. Perform the following steps to clean the Air Inlet system.

1) Turn off the TEOM Control Unit.
2) With the mass transducer in its closed (upright) position, carefully remove the air thermistor from the "cap" of the TEOM mass transducer by pressing in on the metal locking clip. The cap is located immediately above the part of the mass transducer that swivels downward.
3) Open the mass transducer by pulling upward on its silver handle.

4) Place plastic or another protective material over the exposed part of the mass transducer.
5) Clean the Air Inlet using a soapy water, alcohol, or Freon solution. A soft brush may also be used to remove particulate on the inside walls.
6) Allow the air inlet to dry.
7) Remove the plastic or other protective material from the exposed part of the microbalance.
8) Pivot the mass transducer into its closed position by pressing the closing mechanism.
9) Carefully re-insert the air thermistor into the cap of the mass transducer assembly.
10) Turn on the TEOM Control Unit.

6.5 Field Operations and Routine Field Quality Control

Field operations and routine field quality control consists of routine site inspections, filter replacement, and precision checks.

6.5.1 Routine Site Inspections

The PM_{10} monitoring site shall be serviced weekly. Upon entry to the site, the operator enters the site name, date, time, and his name on the TEOM PM_{10} Site Check Record provided as Attachment A. The operator inspects the monitor screen for correct date and time readings, and compares the most recent data to outside observations for reasonableness. The following sections describe the routine field operational and quality control activities that will be performed during the site inspections.

6.5.2 Filter Replacement Procedures

This section discusses the length of the sample filter lifetime and the means by which sample filters are installed and exchanged. The TEOM air sampler must always be operated with a filter cartridge installed in the mass transducer. Install a filter cartridge as described in this Section before applying power to the instrument. Testing performed for official EPA PM_{10} measurements must be conducted with TEOM filter cartridges made of Teflon ® -coated glass fiber filter paper. Filters should be stored inside the sensor unit for easy access and to keep them dry and warm.

Filter lifetime depends upon the nature and concentration of the particulate sampled, as well as the main flow rate setting (3, 2 or 1 L/min). The lifetime is determined by the filter loading, as shown on the status line of the Main Screen. TEOM filter cartridges should be exchanged when the filter loading value is equal to or greater than 75%. Filter lifetime at a main flow rate of 1 L/min is generally 60 days at an average PM_{10} concentration of 50 µg/m3 .

Please note the following instructions when performing a filter exchange. Do not handle new TEOM filter cartridges with fingers. Use the filter exchange tool provided with the instrument to exchange filters. Keep the sample pump running to facilitate filter exchange. Exchange filter cartridges in the following manner.

1) Press the <Data Stop> key on the control unit.
2) Open the door of the sensor unit.
3) Locate the silver handle mounted on the front surface of the mass transducer. Note that there is a shipping latch in the middle of this handle. To open the mass transducer, move the shipping

latch upwards and lift up on the bottom of the handle. Once unlatched, swing the mass transducer downward using the black knob. The TEOM mass transducer then swings into its filter changing position. When the mass transducer is in this open position, the tapered element automatically stops vibrating to facilitate filter exchange.

4) To remove a filter, carefully insert the lower fork of the filter exchange tool under the filter cartridge so that the filter disk is between the fork and the upper plate of the filter exchange tool. The tines of the fork should straddle the hub of the filter base. Gently lift the filter from the tapered element. Never twist the filter or apply sideways force to the tapered element.
5) Place a new filter in the filter exchange tool so that the filter disk lies between the fork and upper disk of the tool (with the hub of the filter between the tines of the lower fork). Do not touch the filter with your fingers – use only the filter tool.
6) Hold the filter exchange tool in line with the tapered element and lightly insert the hub of the filter onto the tip of the tapered element. Ensure that the filter is seated properly. Then apply downward force to set it firmly in place (approximately 0.5 kg or 1 lb).
7) Remove the filter exchange tool by retracting it sideways until it clears the filter. Do not disturb the filter.
8) Gently raise the mass transducer to the closed position using the black knob. Position the silver handle so that it engages the latch plate and push the handle down until the shipping latch is secure.
9) Close and latch the door to the TEOM Sensor Unit. Keep the door open for as short a time as possible to minimize the temperature upset to the system.
10) If the instrument is turned on, reset it by pressing <F1> or <Run> on the keypad of the TEOM Control Unit.
11) IMPORTANT: After five minutes have elapsed, open the sensor unit and mass transducer again. Press straight down on the filter cartridge with the bottom of the filter exchange tool. This ensures that the filter cartridge is properly seated after it has experienced an increase in temperature. Then close the mass transducer and enclosure.
12) If the instrument is turned on, reset it again by pressing <F1> or <Run> on the keypad of the TEOM Control Unit. NOTE: Use the following quick check to ensure that a filter is properly installed soon after installation. Five minutes after installing a new filter in the mass transducer, the change in the tapered element's oscillating frequency as shown on the Main Screen should be in range of 05-10 in the last two digits to the right of the decimal point.

6.5.3 Precision Checks

Because of the high cost of providing co-located continuous TEOM analyzers, flow checks are used instead to assess precision. Procedures and calculations are described in the EPA memorandum *Supplemental Interim Guidance for Quality Assessment of Continuous PM10 Analyzers* dated November 3, 1995, under the "Alternative Procedure" on page 2. The precision check flow rate data is obtained from the analyzer's *actual instrument flow rate* internal flow meter and the set-point is used as the "actual flow rate". The internal flow meter must meet the criteria specified in the EPA memorandum for the "Alternate Procedure" to be permissible. Perform the following steps below to obtain the precision data.

1) Press <Step Screen> if not in the main menu.
2) Scroll using the down arrow key until the Main Flow and Auxiliary Flow are visible.
3) Record the readings on the site record form.

6.6 Data Collection and Validation

This section describes data collection, initial review, and validation.

6.6.1 Data Collection and Initial Review

Collection of data via cellular modem from the TEOM air sampler will be performed using the project database. The data will be collected and reviewed at least three times per week. The data will be visually inspected by the project manager or database manager to determine if the monitor appears to be operating properly and if any data gaps have occurred.

After the data are collected, they will be screened to identify any instrument malfunctions and to invalidate possible incorrect data points before they are archived. The SCREENTEOM program is run to initially screen the data set and flag questionable data records. Parameters including filter loading and status codes are screened against nominal criteria including a status code of either 0 (no status conditions) or 8 (filter needs changing), and a filter loading criteria of 90 to 100 percent. Results of the initial screening are compared to site operator comments to help interpret any unusual events.

A data collection and review log book will be maintained. The project manager or database manager will record the date and time of interrogations and results of screening tests. If any unusual events are noted, the actions taken to evaluate the event will also be recorded. This logbook will be used during data validation and will serve, along with the site log book, as a summary of significant events that occurred.

6.6.2 Data Validation Process

The hourly data output from the TEOM 1400a monitor includes a data status code that will flag any operational condition that is out of limits. Therefore, data will be considered valid unless the status code is any value other than 0 or 8 (8 is the code for filter loading above 90% - this is a notification that the filter needs to be changed, but not an indication of "out-of-calibration" status), the instrument mass transducer noise value is greater than 0.1, or the one-hour PM_{10} concentration is less than zero. A minimum of 18 valid hours of data are required to produce a valid 24 hour block average. The site operator's site inspection notes and calibration and audit results will also be reviewed and considered when data is validated.

During any periods of elevated ambient PM_{10} concentrations, the hourly data from multiple continuous monitors may be evaluated using site-specific meteorological data to determine upwind (i.e., background concentrations) and downwind (i.e., source impacted concentrations) relationships on an hour by hour basis. The hourly data can then be used to construct 24-hour upwind and downwind concentration averages; these 24-hour averages can be used to evaluate the facility's contributions to elevated PM_{10} concentrations.

7.0 INSTRUMENT MEASUREMENT THEORY

The TEOM Series 1400a continuous particulate air sampler is a real time device for measuring the particulate concentration of PM_{10} in ambient air. TEOM instruments are the only filter-based mass monitors that measure the mass of particulate suspended in gas streams in real time. This is made possible by a highly sensitive, yet rugged inertial mass transducer patented in the U.S. and internationally. The monitor is ideally suited for applications demanding real time ambient air particulate monitoring in outdoor, indoor or industrial settings. In its most common configuration, it calculates mass concentration, mass rate and the total mass accumulation on the TEOM filter cartridge using a total flow rate of 16.7 L/min and main flow rate of 3 L/min.

The TEOM air sampler is a true "gravimetric" instrument that draws ambient air through a filter at a constant flow rate, continuously weighing the filter and calculating near real time (10 minute) mass concentrations. In addition, the instrument computes the total mass accumulation on the collection filter, as well as 30-minute, 1-hour, 8-hour and 24-hour averages of the mass concentration. The use of a hydrophobic filter material, along with sample collection at above-ambient temperature (50 °C), eliminates the necessity for humidity equilibration. Both analog and RS-232 outputs are available to transmit the measurements to a user's data system. The instrument's internal storage buffer can store a large amount of data for later viewing on the instrument display or downloading over the RS-232 output.

When the instrument samples, the ambient sample stream first passes through the PM-10 Inlet. At its design flow rate of 16.7 L/min, this inlet passes through particles smaller than 10 µm diameter. At the exit of the PM-10 inlet the 16.7 L/min flow is isokinetically split into a 3 L/min sample stream that is sent to the instrument's mass transducer and a 13.7 L/min exhaust stream. Inside the mass transducer this sample air stream passes through a filter made of Teflon-coated borosilicate glass. This filter is weighed every two seconds. The difference between the filter's current weight and the filter's initial weight (as automatically measured by the instrument after the installation of the filter) gives the total mass of the collected particulate. These instantaneous readings of total mass are then smoothed exponentially (using a selectable time constant) to reduce noise. Next, the mass rate is calculated by taking the increase in the smoothed total mass between the current reading and the immediately preceding one and expressing this as a mass rate in g/sec. This mass rate is also smoothed exponentially to reduce noise.

The weighing principle used in the TEOM mass transducer is fundamentally different from that on which most other weighing devices are based. The tapered element at the heart of the mass detection system is a hollow tube, clamped on one end and free to vibrate at the other. An exchangeable filter cartridge is placed over the tip of the free end. The sample stream is drawn through this filter, and then down the tapered element. This flow is maintained at a constant volume by a mass flow controller that is corrected for local temperature and barometric pressure. The tapered element vibrates precisely at its natural frequency, much like the tine of a tuning fork. An electronic control circuit senses this vibration and, through positive feedback, adds sufficient energy to the system to overcome losses. An automatic gain control circuit maintains the vibration at constant amplitude. A precision electronic element enables the high-resolution measurement of particle mass collected on the sample filter.

The tapered element is in essence a hollow cantilever beam with an associated spring rate and mass. As in any spring-mass system, if additional mass is added the frequency of the vibration decreases. This can be seen by observing the frequency on the four-line display of the TEOM Control Unit. In a spring-mass system the frequency follows the equation $f = (K / M)0.5$ (1), where f = frequency (radians/sec), K = spring rate, M = mass, and K and M are in consistent units. Ko (the calibration constant for the instrument) can be easily determined by measuring the frequencies with and without a known mass (pre-weighed filter cartridge).

The TEOM air sampler is composed of two major components: the TEOM Sensor Unit and TEOM Control Unit. System parameters are entered by the user from the keypad on the front of the control unit. Additionally, the system is furnished with software for IBM AT-compatible personal computers to view the operation of the instrument in real time, and to allow for the optional entry of system values from the computer. The sensor unit contains the mass measurement hardware that allows for the continuous monitoring of accumulated mass on the system's exchangeable filter cartridge. By maintaining a flow rate of 3 L/min through the instrument and measuring the total mass accumulated on the filter cartridge, the device can calculate the mass concentration of the sample stream in real time. The control unit houses an industrially-hardened microprocessor system, flow control hardware, a gauge to determine filter lifetime, transformers and power supplies.

8.0 References

RTP Environmental Associates, Inc., 2002. SOP 169 – TEOM 1400 PM_{10} Monitor. Revision 2. December 14.

Tisch Environmental, Inc., 1999. Operations Manual PM10 High Volume Air Sampler. February 1.

U.S. Environmental Protection Agency, 1998. Reference Method for the Determination of Particulate Matter as PM-10 in the Atmosphere. 40 CFR, Chapter I, Appendix J to Part 50. July 1.

9.0 Attachments

ATTACHMENT A TEOM PM_{10} Site Check Record

ATTACHMENT A

TEOM PM_{10} Site Check Record

TEOM PM10 SITE Check Record

Date: Time:

Site ID: Operator ID:

Record the data from the first line of the main status screen. If the line does not begin with "OK", call RTP with the data – if the % reading is greater than 70%, it is time to replace the filter.

Main Flow should be 3.00 $\pm$ 0.06, and Aux Flow should be 13.67 $\pm$ 0.27.

Status Line	
Main Flow	
Auxiliary Flow	

Record shelter temperature and adjust if necessary:

Check the inline filters – if they are dirty, call RTP to determine if they should be switched.

Check the connection between the sensor unit and the inlet tubing coming in from the top of the roof. Does it look tight?

Visually check the top of the sampler for damage or obstructions:

Record the general weather conditions and dust levels: